An Expanded Definition of Shoals Along the Middle Atlantic Bight, North America

by

Laura L. Schrock

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Thesis Advisor

Gary D. McManus 11/24/86

Department of
Geology and Mineralogy

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Abstract

Shoals along the Middle Atlantic Bight are divided into two major groups, linear shoals and arcuate shoals. Linear shoals include shoreface-connected shoals and isolated shoals. Arcuate shoals are either cape-associated or inlet associated. Excellent examples of linear and cape-associated shoals are found off of the coast of North Carolina.

Three hypotheses for the origin of shoals are presented. All are based on a rise in sea level and the subsequent shoreface retreat. Modern hydraulics, in the form of waves and currents, appear to influence the formation of shoals.

Introduction

The Atlantic continental shelf of the United States has superimposed on it a series of ridges and swales. Although this topography was known by early seafarers, it was not until the 1920s that techniques were used to examine the inner ocean floor. Studies of that data revealed that the ridge and swale topography was made up of smaller elements including shelf-transverse valleys, deltas, scarps, and shoals. Since the scientific discovery of these submarine features there have been many theories incorporating the ridge and swale topography into the evolution of the continental shelf. The study of shoals has played an important role in an understanding of the history and possible future of the shelf surface. The classification and analysis of the different shoals on the Atlantic coast is the first step in understanding why the ridge and swale topography is so prominent and how the inner continental shelf is evolving.

In the Middle Atlantic Bight all five of the major shoal types are present. The North Carolina coast and its associated shoals are discussed in this paper. These shoals are important because they are prime examples of the various shoal types that are found all along the continental shelf as well as in the Southern Bight of the North Sea.

Types and Definitions of Shoals

Shoals are elevated surfaces of the ocean floor that are composed of materials other than rock or coral. Quartz sand is

the most common constituent although carbonate material such as shell fragments may be present off the Florida coast, for example. The sand is generally medium-grained and textures are similar to those sands found on adjacent beaches. Samples of sands from linear shoals near Assateague Island in Maryland have grains ranging from 0.203 mm to 0.400 mm in diameter. These sands are slightly finer than those found on adjacent beaches (Duane et al., 1972). The height of the shoals may be as much as 9 m and side slopes generally average between 3 and 10 degrees. Shoals may extend for up to 16 km along the sea floor (Duane et al., 1972). A classification of shoals based on their morphology and location is given by Duane et al. (1972). Two major categories, linear shoals and arcuate shoals, are presented. Linear shoals may be further subdivided into those which are shoreface-connected and those which are isolated. Arcuate shoals may either be cape-associated or inlet-associated.

In order for a shoal to be considered linear it must have a relief of at least 3 m above the surrounding surface. Linear shoals nearly all form a small angle with the coastline and are oriented in a northeast-southwest direction (Figure 1).

Shoreface-connected linear shoals maintain an angle of approximately 20° with the shoreline regardless of the shoreline orientation (Swift et al., 1973). It is important to note however, that these shoals are never parallel to the shoreline. These shoals are connected to the shore in the sense that there is a gradual increase in relief on the ocean floor. This relief

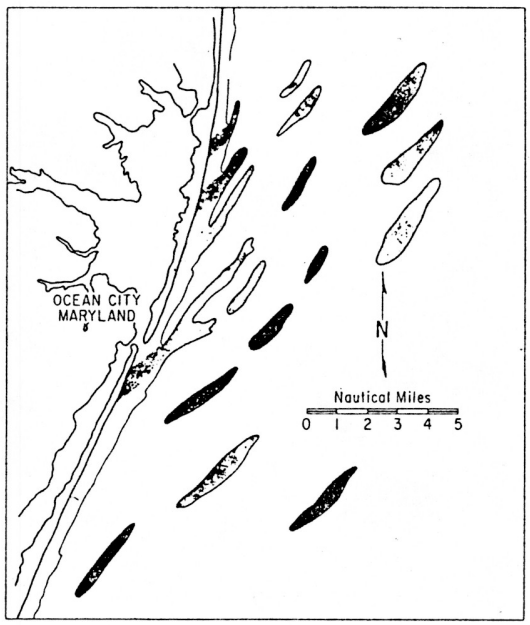

Figure 1. A schematic drawing of shoreface-connected and isolated linear shoals showing their angular relationship with the coastline (after Duane et al., 1972).

extends linearly from the shore and is termed a shoal when the relief is in excess of 3 m. Shoreface-connected shoals are generated by nearshore processes, mainly currents.

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Isolated shoals appear to be shoreface-connected shoals which have undergone detachment form the shore. Another possibility is that isolated shoals formed when a discontinuity existed in a shoreface-connected shoal, thus resulting in a portion of the shoal being broken off (Figure 2). If a shoal underwent detachment from the shore it suggests that there was an alteration in the nearshore processes which formed the shoal. This may be accomplished by a rise in sea level which causes a retreat of the shoreline.

Arcuate shoals differ from linear shoals in that they do not have a specific orientation to the shore and they have a curved or bowed appearance in plan view. The classification of arcuate shoals is based on where they are located. Cape-associated arcuate shoals appear to be submarine extensions of capes which commonly occur on the tips of cuspate forelands. Examples include Capes Hatteras, Lookout, Fear, Romain, and Kennedy. For all of the capes mentioned above, the predominant direction of wave ap-

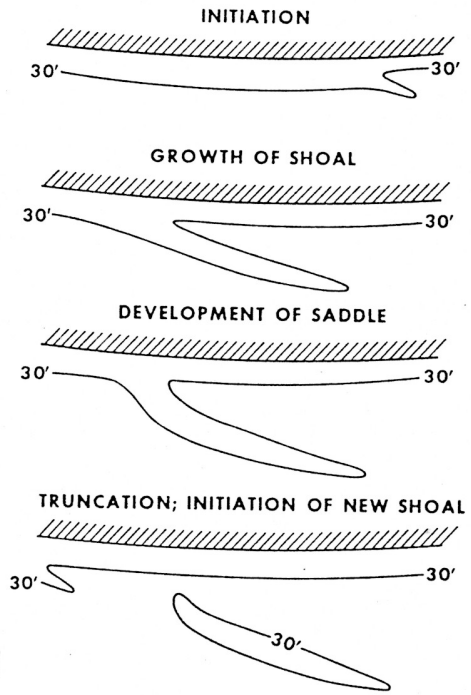

Figure 2. Evolution of an isolated shoal (after Duane et al., 1972).

proach is from the northeast. The littoral currents which result converge at the tip of each cape. The sand which is transported by these currents is deposited at the apices, thereby forming shoals which extend off of the capes. An opposing theory on the formation of cape-associated shoals is that the shoals were formed in response to the rise in sea level and subsequent shoreface retreat. In a study conducted by Swift et al. (1972) on the Diamond Shoals off of Cape Hatteras it was shown that the shoals were not growing seaward due to convergence of sand at the cape apex. Instead, the southward increasing asymetry of the shoals suggest that they are actually the remnants of the cape itself (Figure 3). This asymetry is also a feature of all of the shoals present off of the capes which were previously mentioned (Figures 4 and 5).

Shoals associated with inlets make up the second type of arcuate shoal. Large estauries are common on the Atlantic coast of the U.S., and shoals associated with these estuaries tend to be seaward convex and concentric around a scour trench (Swift et al., 1976). Many of the trenches present on the Atlantic coast are relict channels of the estuary mouths. These trenches and their associated shoals mark the path of the retreat of the estuary along the continental shelf floor. Because the dominant direction of sediment input is from the north, the northern ends of the shoals exhibit the greatest relief. Exemplifying this are the inlet shoals present at the mouth of Chesapeake Bay. These shoals have a relief of 15 to 20 meters on their northern ends and 5 to 10 meters less relief on other portions (Swift et al., 1973).

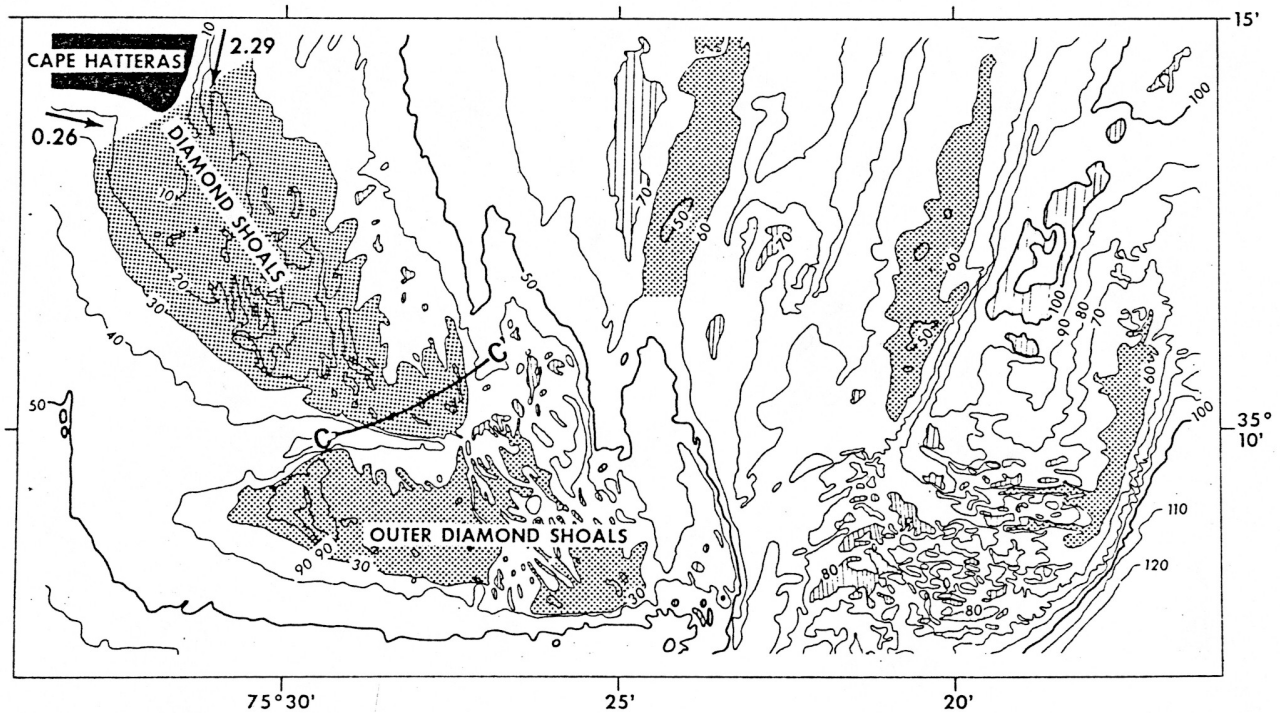

Figure 3. The Diamond Shoals off of Cape Hatteras, North Carolina. Major isolated highs are stipled (after Swift et al., 1972).

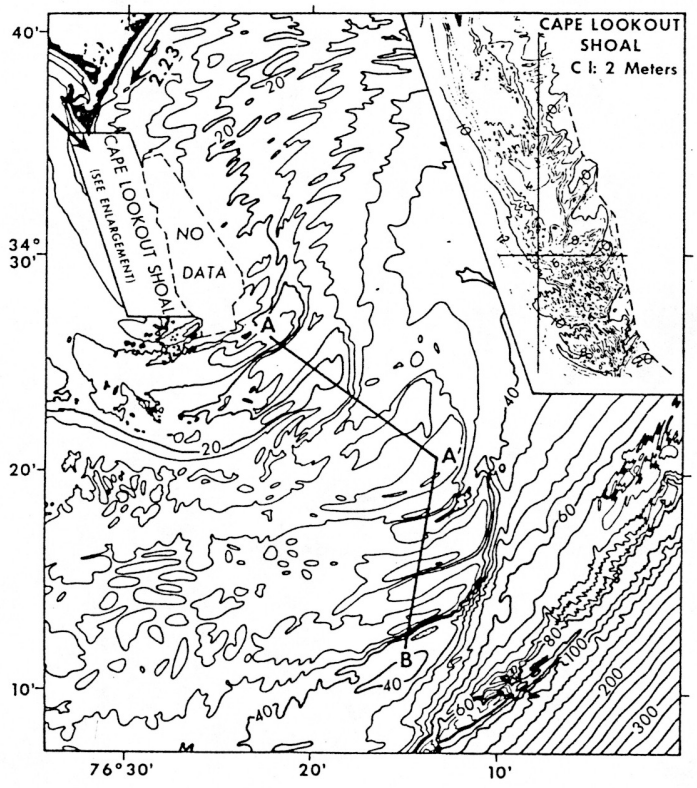

Figure 4. Cape Lookout Shoals, North Carolina (after Swift et al., 1972).

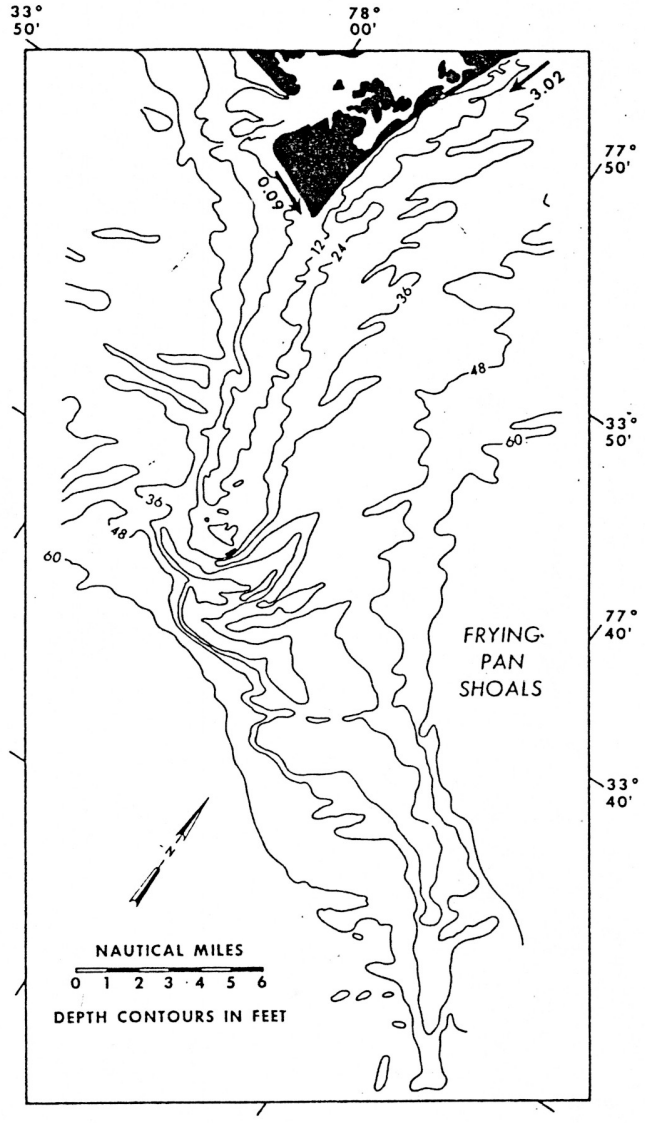

Figure 5. Frying Pan Shoals off of Cape Fear, North Carolina (after Swift et al., 1972).

Shoals are also present at inlets located between barrier islands. However, these shoals do not exhibit relief as great as those associated with large estuaries, thus making them more difficult to study.

Shoals Along the Coast of North Carolina

Along the coast of North Carolina four out of five of the major shoal types are present. The most prominent of these shoals are those which are associated with the three major capes; Capes Lookout, Fear, and Hatteras. All of these cape-associated shoals have the same basic configuration except for one major factor. In the vicinity of the Diamond Shoals at Cape Hatteras, the continental terrace is only 30 km wide. South of this area the shelf widens and reaches widths up to 130 km. This width remains nearly constant until it narrows near Jacksonville, Florida. Over one half of the width of this terrace off of Cape Hatteras consists of the Diamond Shoals. In this area water depths may be as little as 10 meters. The depths of waters over Lookout Shoals and Frying Pan Shoals off of Cape Fear average around 55 meters (Shepard, 1973).

Farther north of Cape Hatteras there is a linear shoal complex known as the Platt Shoals. These shoals are located adjacent to Oregon Inlet (Figure 6). The complex is comprised of two major groups, Inner Platt Shoals and Outer Platt Shoals. Inner Platt Shoals are shoreface-connected by a low saddle and have a maximum relief of 9 meters. The Outer Platt Shoals are southeast

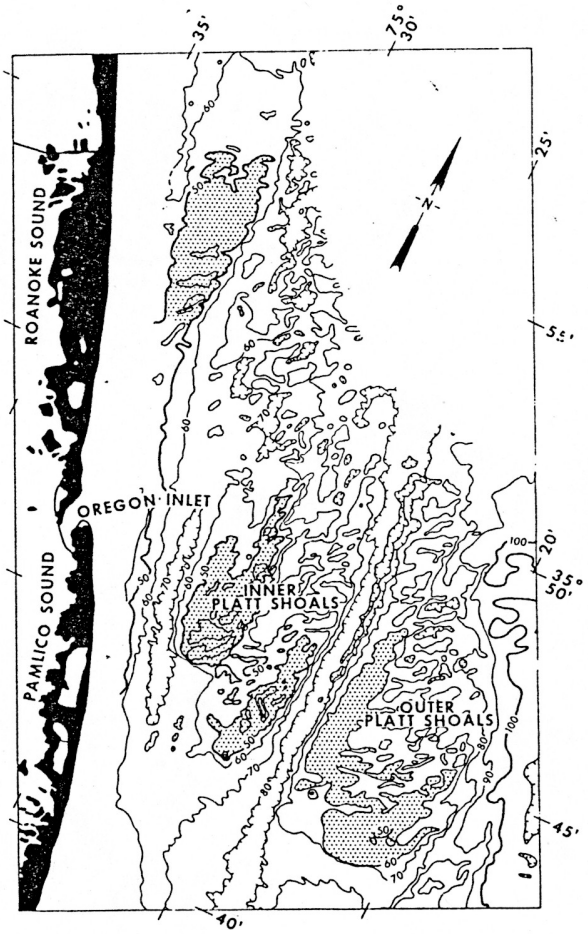

Figure 6. The Platt Shoals off of the coast of North Carolina (after Duane et al., 1972).

of the Inner Platt Shoals and are of comparable relief. Both of these shoals are separated by a trough which is approximately 18 meters deep. The Outer Platt Shoals are isolated but were once connected to the shoreface by their northern counterpart. The presence of a trough between the two shoal groups may be related to the creation of the isolated Outer Platt Shoals. The deepening and headward erosion of the trough suggests that the shoreface connected shoal is branching off and forming an isolated shoal (Duane et al., 1972).

Along the North Carolina coast there is a lack of inlet-associated shoals. This is due to the fact that the three main estuary regions, Currituck, Albemarle, and Pamlico, are all isolated from the major wave and current action of the sea by a series of barrier islands. Virtually the entire North Carolina coast is protected by these barrier islands. This is a feature which is unlike the coasts to the north and south. One of the largest estuaries on the Atlantic coast is located just north of these barrier islands. The Chesapeake Bay, which was previously discussed, is an excellent example of inlet shoals associated with an estuary.

Theories on the Formation of Shoals

Although shoals may be classified systematically, their formation is still a subject of controversy. Three major hypotheses for the origin of shoals are present throughout the literature. In 1939, Veatch and Smith suggested that the ridge and

swale topography was due to wave planation with terraces and other distinctive forms representing progressive steps of the advancing sea. Although this hypothesis is favored by investigators such as Shepard (1973), Swift et al. (1974) point out that this requires that the advancing sea deposit a layer of littoral sand and that the terrestrial surface must be preserved.

A second hypothesis is that the shoals represent relic beach ridges and may be correlated to subaerial beach ridges on the adjacent coast. This correlation is nearly impossible if one considers that linear shoals intersect the shoreface at an angle and are rarely ever parallel to subaerial beach ridges. In order for this correlation to exist, there must have been a drastic reorientation of the shoreline.

The third hypothesis is that the ridge topography is formed when shoreface retreat causes older beach deposits to be consumed and reshaped by the processes of the sea. Out of the three major hypotheses, the latter is the only one which incorporates modern hydraulics with the formation of shoals. Studies on the ridges off of the Delaware coast determined that the ridges shifted during the Ash Wednesday storm of 1962 (Swift et al., 1972). This is evidence that the shoals are subject to modern wave and current action. This, in turn, suggests that modern hydraulics play an active role in the formation of the ridge and swale topography.

Conclusions

Although the formation of shoals is questionable, modern hydraulics appear to play a large part in their formation. The

formation of inlet-associated shoals is less understood than the other types of shoals. Most shoals of this type appear to be influenced by modern hydraulics, but they often resemble ancient deltaic or river mouth sediments. Very little information on this subject is present in the literature. Presumably, these fluvial sediments have undergone considerable reworking by waves and currents, thereby making them indistinguishable from other beach material in the area. In most cases, the only connection these sand bodies have to a deltaic origin is their relative orientation and overall configuration in plan view.

It is clearly evident that further studies on shoals need to be conducted if one is to completely understand their relationship with the continental shelf. The classification and description of the shoals present in the Middle Atlantic Bight is the first step to understanding the significance of shoals.

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